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WIPPGET 1

APR 3 1987

MEMORANDUM FOR: John Trapp, Acting Section Leader
Geology/Geophysics Section
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FROM: Jim Warner
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SUBJECT: TRIP REPORT FOR WIPP VICINITY GEOTECHNICAL FIELD TRIP

Please find attached a trip report for a geotechnical field trip in the vicinity of the Waste Isolation Pilot Plant (WIPP), Carlsbad, New Mexico. If you should have any questions about the trip or contents of the report, please contact me.

/s/

Jim Warner
Geology/Geophysics Section
Geotechnical Branch

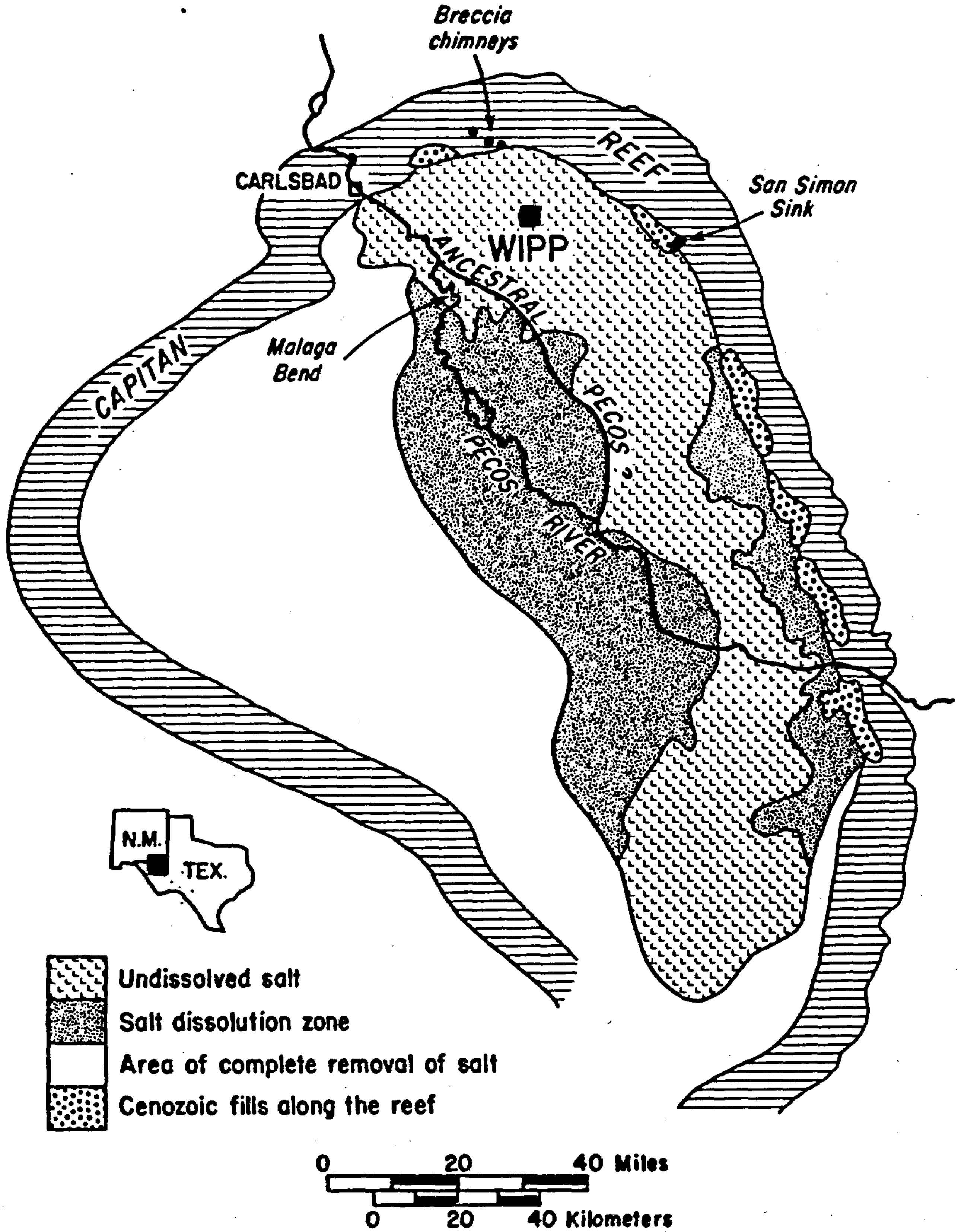
Introduction

On February 27, 1987, Tom Cardone (WMGT-Salt Team), Jim Warner (WMGT-Salt Team), and eight scientists from Argonne National Lab (SCP Review Group for SRPO) participated in a geotechnical field trip in the vicinity of the Waste Isolation Pilot Plant (WIPP), near Carlsbad, New Mexico (fig. 1). The trip was conducted by Dr. Lokesh Chaturvedi and Jenny Chapman of the Environmental Evaluation Group (EEG), State of New Mexico. Participants had the opportunity to learn about:

- the late Permian to recent geologic history of the Delaware Basin
- evaporite dissolution
- pressurized brine occurrences in the Castile Formation
- hydrologic issues associated with the WIPP
- the natural resource potential of the northern Delaware Basin (hydrocarbons, potash)
- the general history of the WIPP

Background Information

The Waste Isolation Pilot Plant (WIPP), a Department of Energy (DOE)-operated facility (nominal depth-2160 ft) in bedded salt of the Permian (Ochoan) Salado Formation, will be used for the permanent disposal of defense transuranic waste (TRU) and experimental activities to determine the feasibility of disposing of high-level radioactive waste (HLW) (DOE, 1980; Matalucci et al., 1982; WIPP-DOE-161, 1983; Weart, 1985; and Matalucci, 1986). Sandia National Laboratory (SNL) is conducting the on-going geotechnical



Breccia chimneys
REEF
CARLSBAD
WIPP
San Simon Sink
ANCESTRAL
Malaga Bend
CAPITAN
PECOS
PECOS
RIVER
N.M.
TEX.
Undissolved salt
Salt dissolution zone
Area of complete removal of salt
Cenozoic fills along the reef
0
20
40 Miles
0
20
40 Kilometers

Figure 1

investigation of the area, Bechtel, Inc. designed the facility, and Westinghouse Electric Company is responsible for facility operations (Weart, 1985). Three primary shafts (waste handling, exhaust, and construction/salt handling shafts), many of the surface facilities, and the underground experimental rooms have been completed (Weart, 1985). In-situ testing without radioactive materials has been underway since 1984, and experiments utilizing radioactive materials are scheduled to begin in 1988 (Weart, 1985; Matalucci, 1986). Although the site validation report (DOE, 1983) declared the site to be suitable, further testing is needed to develop an increased understanding of potentially significant geologic/hydrologic processes associated with the area (Neill et al., 1983).

Environmental Evaluation Group (EEG)

In 1978, the Environmental Evaluation Group (EEG) was established within the New Mexico Environment and Health Department through a grant from the DOE. The purpose of the EEG is to conduct an independent technical evaluation of the possible adverse radiological effects of the WIPP. The group, being neither a proponent nor an opponent of the WIPP, conducts assessments of WIPP-related documents and generates health risk scenarios. Dr. Chaturvedi is an engineering geologist with the EEG, and Jenny Chapman is an EEG staff hydrogeologist.

Geology and Hydrology

The WIPP site is located in the north-central portion of the Delaware Basin (fig. 1), which accumulated a thick section of Permian sediments that dip gently to the east by virtue of Cenozoic tilting. Only the rock units of relevance to the field trip will be discussed, and the reader is referred to Adams (1944), Anderson et al., (1972), Brokaw et al., (1972), Austin (1978), Powers et al., (1978), Bachman (1980), Snyder and Gard (1982), Lambert (1983), and Chaturvedi and Rehfeldt (1984) for a more complete description of the geology and hydrology of the region.

The WIPP is situated within the upper Permian (Ochoan Series), salt-bearing Salado Formation; thus, geologic studies associated with the project have generally been focused upon upper Permian (Guadalupian and Ochoan Series) and younger strata. These units are summarized in figures 2b and 3, and shown diagrammatically in figure 2a.

During the latter part of Guadalupian time, the Delaware Basin was fringed by the Capitan Reef (Capitan Limestone), with clastic deposition in the basin (Bell Canyon Formation) and carbonate/clastic/evaporite sedimentation behind the reef (Artesia Group - Grayburg, Queen, Seven Rivers, Yates, and Tansill Formations) (figs., 1, 2, and 3). The Capitan limestone is presently exposed in uplifted regions along the western and southern margins of the basin. During Ochoan time, the marine water of the Delaware Basin was isolated from world ocean circulation, leading to the deposition of extensive evaporites (Castile, Salado, and Rustler Formations) and finally redbeds (Dewey Lake Formation) (figs. 2 and 3). The Castile Formation (1350 ft thick at the WIPP) is composed of anhydrite-calcite laminated rocks (varves) interbedded with halite. The Salado Formation (1,976 ft thick at the WIPP) consists of 85-90% halite, with interbedded anhydrite, fine terrigenous clastics, and potash minerals (McNutt Potash Zone-polyhalite, sylvite, etc.) (fig. 3). The McNutt Potash Zone of the Salado Formation has been/is extensively mined for potash, and the lower member of the Salado is the WIPP repository host-rock. The Rustler Formation (35-480 ft thick near the WIPP; thickness dependent upon the amount of dissolution at a given location) is composed of anhydrite, halite, terrigenous clastics, and dolomite (Culebra and Magneta Dolomites) (fig. 3). The Dewey Lake Formation (0-560 ft thick near the WIPP) consists of red sandstone and siltstone. Overlying the Permian section are Triassic terrigenous clastics (Dockum Group), minor Cretaceous limestone (not present within the WIPP site), Miocene/Pliocene terrigenous clastics (Ogallala Formation) (not present within the WIPP site), and Pleistocene clay/sand/gravel (Gatuna Formation) and pedogenic caliche (Mescalero Caliche) (figs. 2 and 3).

The Capitan limestone is an important aquifer in the region, and poor quality water is present in sandstone and limestone (Lamar Member) of the Bell Canyon Formation, fractured anhydrite of the Castile Formation (pressurized brine), the Salado/Rustler interface where dissolution has occurred, and the Culebra and Magenta Dolomites (Brokaw et al., 1972; Lambert, 1983; Neill et al., 1983; Chaturvedi and Rehfeldt, 1984). The relevance of these

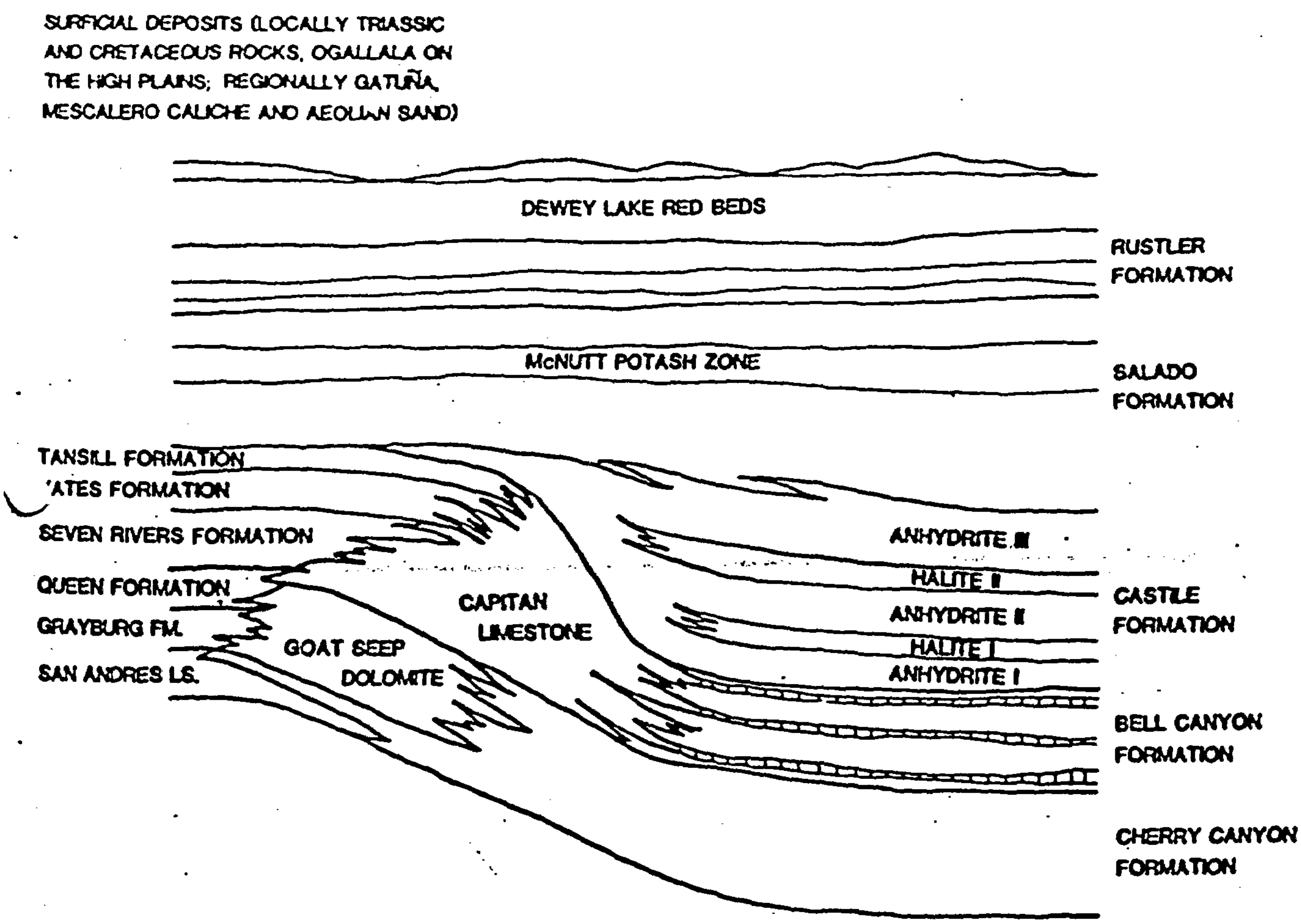


Figure 2a Diagrammatic Cross Section Near the Delaware Basin Margin. Shows stratigraphic relationships among some Permian and younger rocks (compiled from several sources)

<table>
<tr><th></th><th></th><th></th><th>SHELF AREA (BACKREEF)</th><th>MARGINAL AREA (REEF)</th><th>DELAWARE BASIN</th></tr>
<tr><td rowspan="10">PERMIAN</td><td rowspan="4">OCHOAN SERIES</td><td rowspan="4"></td><td>DEWEY LAKE RED BEDS</td><td>DEWEY LAKE RED BEDS</td><td>DEWEY LAKE RED BEDS</td></tr>
<tr><td>RUSTLER FORMATION</td><td>RUSTLER FORMATION</td><td>RUSTLER FORMATION</td></tr>
<tr><td>SALADO FORMATION</td><td>SALADO FORMATION</td><td>SALADO FORMATION</td></tr>
<tr><td>NO CASTILE EQUIVALENT</td><td>NO CASTILE EQUIVALENT</td><td>CASTILE FORMATION</td></tr>
<tr><td rowspan="6">GUADALUPIAN SERIES</td><td rowspan="5">ARTESIA GROUP</td><td>TANSILL FORMATION</td><td rowspan="3">CAPITAN LIMESTONE</td><td rowspan="3">BELL CANYON FORMATION</td></tr>
<tr><td>YATES FORMATION</td></tr>
<tr><td>SEVEN RIVERS FORMATION</td></tr>
<tr><td>QUEEN FORMATION</td><td rowspan="2">GOAT SEEP DOLOMITE</td><td rowspan="3">CHERRY CANYON FORMATION</td></tr>
<tr><td>GRAYBURG FORMATION</td></tr>
<tr><td></td><td>SAN ANDRES LIMESTONE</td><td>SANDSTONE TONGUE
BASINWARD EXTENT ?</td></tr>
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Figure 2b Correlation Diagram for Some Permian Rocks in the Vicinity of the Delaware Basin (after Hayes, 1964)

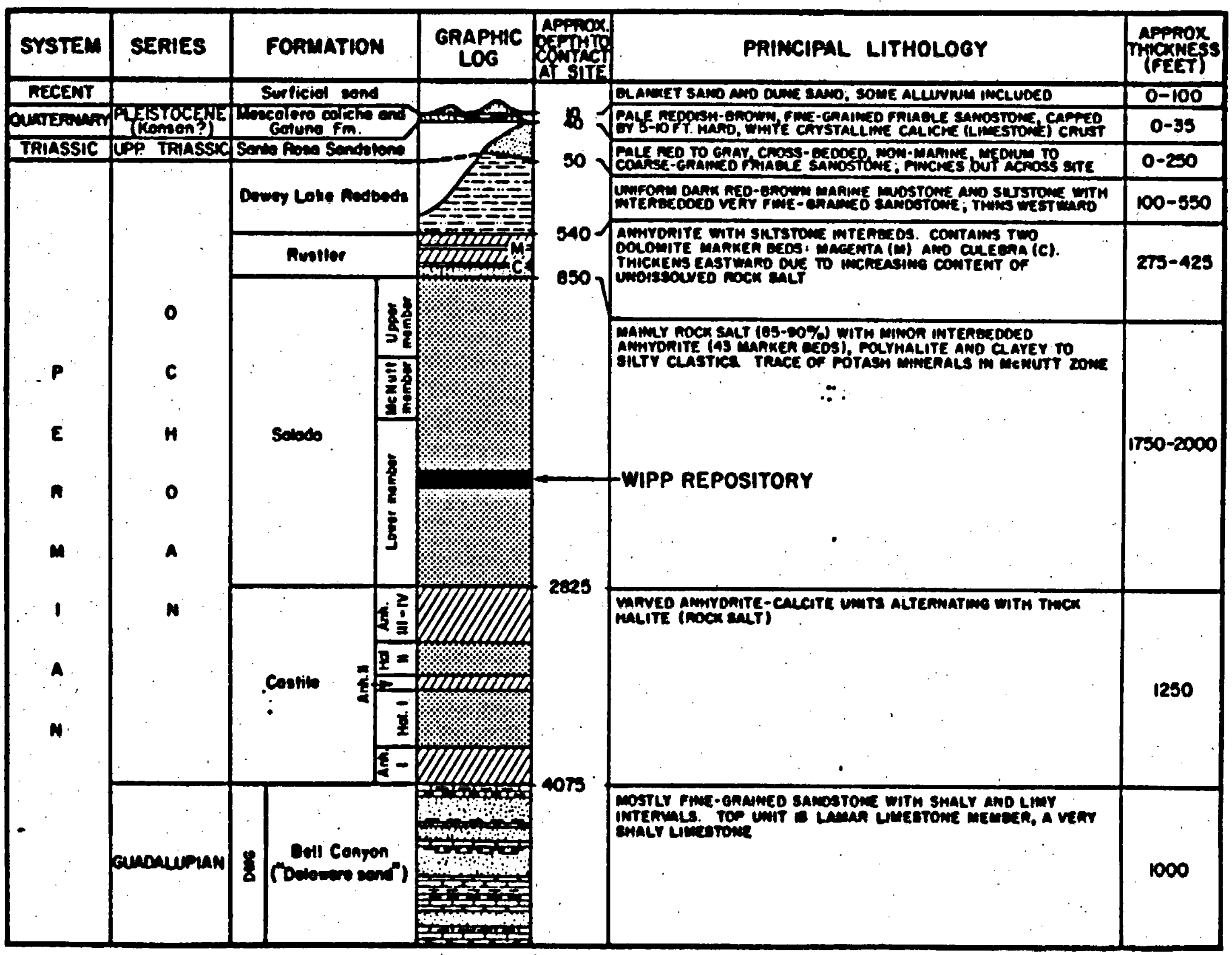

Fig. 3 Generalized stratigraphy at the WIPP site. (Adapted from Powers, et al., 1978.)

water-bearing units to the performance of the WIPP is an unresolved issue (Anderson, 1978 and 1981; Lambert, 1983; Neill et al., 1983; Chaturvedi and Rehfeldt, 1984).

Field Trip

The field trip partially followed the itinerary of a more comprehensive trip that was conducted by the EEG on June 16-18, 1980 (see Chaturvedi, 1980). The original trip was organized to examine field evidence for various hypotheses related to evaporite dissolution and groundwater dynamics in the vicinity of the WIPP. Since that time, some issues have been resolved, and new ones have emerged (compare Chaturvedi, 1980, with Neill et al., 1983). At the present, there appears to be a consensus that shallow salt dissolution is occurring in the upper Salado and Rustler Formations (to produce features such as Nash Draw) in response to meteoric water circulation near the surface ("solution and fill" dissolution) and along relatively permeable beds (fractured anhydrite, fractured dolomite, Salado/Rustler interface) as a dissolution front that is advancing from west to east down the regional dip of the strata ("stratabound" dissolution) (Bachman, 1980; Lambert, 1983; Neill et al., 1983). However, Anderson's theory of deep-seated "brine density flow" (Anderson, 1978 and 1981), resulting in the preferential dissolution of salt between the Halite 3 Unit of the Castile and the 136 marker bed of the Salado by groundwater from the Bell Canyon Formation or the Upper Anhydrite Unit of the Castile, remains debated (Anderson, 1981; Lambert, 1983; Neill et al., 1983). The significance of deep-seated breccia chimneys is not fully understood, although they have most recently been attributed to collapse in the underlying Capitan limestone (Synder and Gard, 1982). Two issues that have gained importance since the original field trip are the occurrence of pressurized brine in fractured anhydrite of the Castile Formation, and the potential significance of radionuclide transport by groundwater in the Culebra Dolomite (Neill et al., 1983); thus, the recent field trip addressed these topics in addition to dissolution.

Summary of the Field Trip-February 27, 1987

In the morning, the participants from the EEG, Argonne, and the NRC met at the Holiday Inn in Carlsbad, and were given a short presentation by Dr. Chaturvedi (a list of participants is included as appended material). Dr. Chaturvedi furnished us with several handouts, reviewed the Permian to recent geologic history of the Delaware Basin, discussed the significance of each field trip stop (this information is included in the next section), and made several points including:

- Neill et al., (1983) is a summary of the EEG's position on various WIPP-related technical issues and their recommendations for issue-resolution.

- Actual evaporite dissolution, original depositional variability, and problems associated with determining the age of dissolution all combine to make the process of assessing the significance of zones of "missing halite" difficult.

- Based upon estimated rates of horizontal (6-8 mi/million yr) and vertical (330 ft/million yr) dissolution along known dissolution "fronts" (Nash Draw), the EEG has concluded that shallow or "blanket" dissolution (including "solution and fill" and "stratabound" dissolution) does not pose a threat to the WIPP during it's planned effective lifetime (Neill et al., 1983). In contrast, deep-seated dissolution (Anderson, 1978, 1981) is more difficult to identify and predict, although the WIPP appears to be well situated with respect to postulated deep-seated dissolution zones.

- The EEG has suggested that the DOE conduct further studies into the hydrologic characteristics of the Culebra and Magenta Dolomites, which are considered to be potential pathways for the groundwater transport of released radionuclides to the Pecos River in the event of a repository breach followed by the upward migration of radioactive contaminants (Neill et al., 1983).

- The amount of total dissolved solids (TDS) in the Culebra Dolomite shows a high degree of variability (in terms of bulk amount and specific chemical constituents) between wells in the vicinity of the WIPP (Ramey, 1985). The distribution of TDS in the groundwater is not consistent with hydraulic head data, which indicates groundwater in the Culebra Dolomite flows southeast from the WIPP site to Malaga Bend (fig. 4)(Neill et al., 1983). The EEG has recommended that the DOE conduct an investigation of the hydrology and hydrochemistry of the Culebra Dolomite (Neill et al., 1983).

Figure 4 is a map of the Carlsbad area showing the location of the field trip stops, which are designated with circled numbers (fig. 4) and summarized below.

Stop 1: Capitan Reef

Stop 1 is an outcrop of Capitan Limestone (Reef) that is located along the western margin of the Delaware Basin. The Capitan limestone is massive, highly fossiliferous, and can be extremely permeable (as evidenced by Carlsbad Caverns); thus, this unit strongly influences the movement of groundwater in the region. Approximately 1 to 2 miles west (Shelfward) of this location, the reef grades laterally into the bedded carbonates of the Yates and Tansill Formations (backreef facies).

Stop 2: Castile Formation-State Line Outcrop

Stop 2 provides excellent exposure of the varved Castile Formation, dissolution breccia of the Castile Halite 3 Unit, and microscopic and mesocopic folding of debatable origin.

At this location, the Castile is composed of thin alternating laminations of anhydrite and calcite (see Anderson et al., 1972), and a limestone marker bed. Anderson (in Chaturvedi, 1980) uses a basinward (Southward, eastward) thickening of the Castile Halite 3 Unit above the limestone marker bed and dissolution-related breccia at this outcrop to show that the Halite 3 Unit salt has been preferentially dissolved in this portion of the basin.

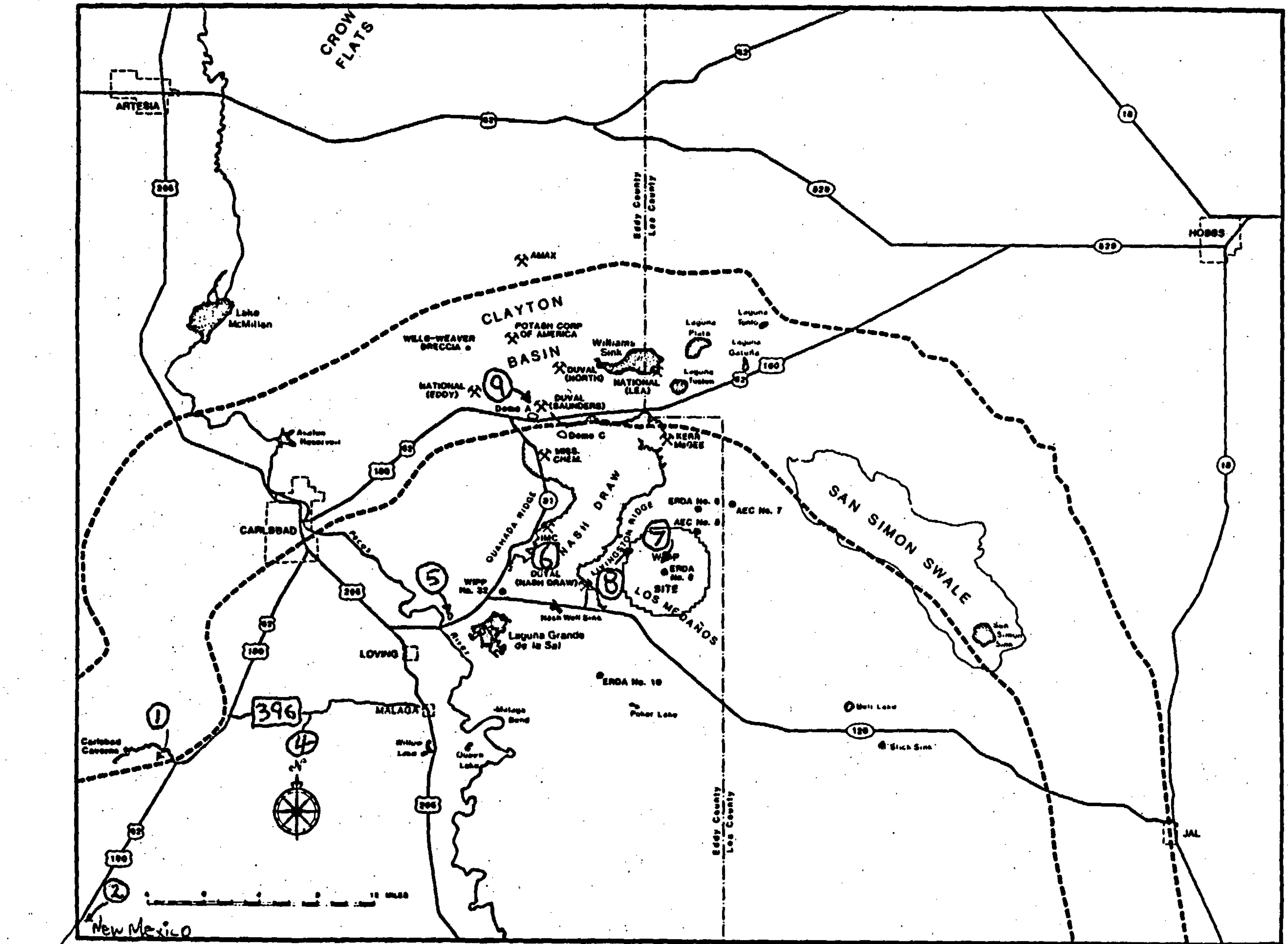

Figure 4 Geomorphic Features in the Northern Delaware Basin, Southeastern New Mexico. Identified features are those inferred by various sources to have relevance to evaporite dissolution. Heavy broken lines are the approximate basinward (south) and shelfward (north) limits of the Capitan limestone. The lower and right-hand boundaries of the figure are the New Mexico-Texas State Line.

The circled numbers refer to the field trip stops discussed in the text.

The dissolution breccia consists of angular blocks of varved Castile strata, in which the laminations truncate those of adjacent blocks. Some of the blocks are separated by gypsum-filled fractures, while others appear to be lithified together.

The Castile Formation at this outcrop displays a diverse set of small scale fold styles (open to isoclinal; upright to recumbent; opposite vergence and conjugate box folds) and is gently folded on a mesoscopic scale. Anderson (in Chaturvedi, 1980) maintains the orientation of folds at this location conforms to the structural grain of the basin, which implies the folds are a result of Cenozoic basin tectonics. Anderson (in Chaturvedi, 1980) also believes these structures are related to folds in the Castile Anhydrite 2 Unit from borehole ERDA-6 (fig. 5), where post-folding salt flowage has disrupted the folds. This is used as evidence that the salt movement that created the "disturbed zone" (a zone of folded, fractured, and faulted Castile strata), which encompasses an area including the northern portion of the WIPP site (Neill et al., 1983), is a young or presently active feature. However, Dr. Chaturvedi pointed out that the inconsistent style and lack of vertical persistence of the folds at the state line outcrop have led to alternative interpretations (sedimentary ripples, soft sediment deformation, volume change during anhydrite to gypsum transformation) for their origin.

<u>Stop 3: Limestone Buttes (Castiles)</u>

At this location we observed several limestone buttes that consist of finely laminated and brecciated limestone, and stand well above (over 70 feet) the surrounding gypsum plain. These "Castiles" are thought to represent resistant plugs where calcite has replaced the anhydrite-calcite varved Castile Formation seen at the preceeding stop. The original varved texture is preserved in the brecciated limestone and can be seen in unaltered portions of the outcrop. It has been suggested that the "Castiles" represent collapsed breccia chimneys where sulfate-reducing fluids rose from the underlying Bell Canyon Formation to drive the replacement process.

ERDA-6 (approximate)

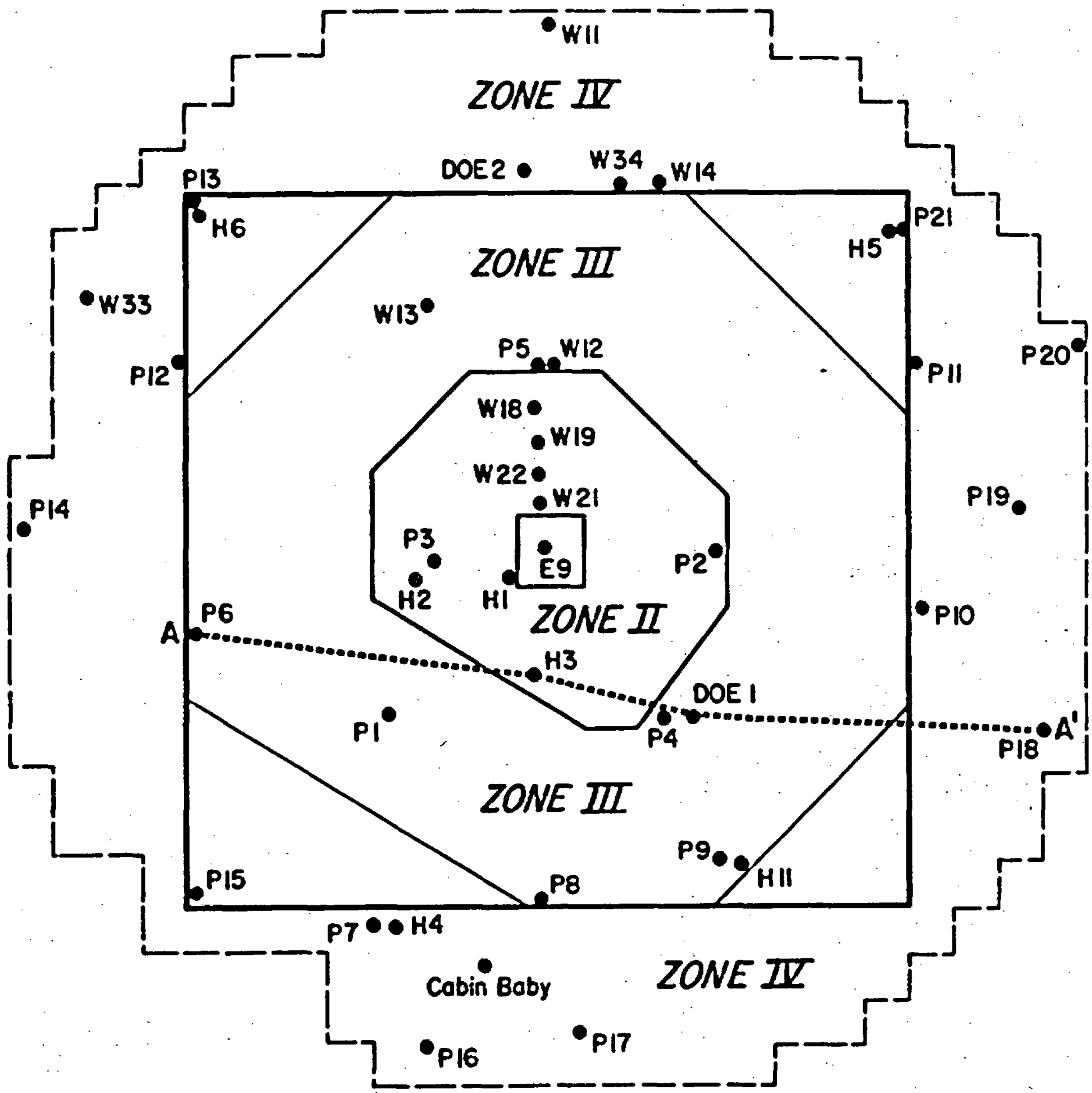

Figure 5. The distance between Well E9 and well W12 is approximately 1 mile.

Stop 4: Salado Intraformation Dissolution Breccia

The chaotically brecciated dissolution residue (terrigenous clastic material, iron oxides, gypsum, soil) exposed at Stop 4 has been through several stages of leaching, recrystallization, and collapse. Dr. Chaturvedi stated that the approximately 20 feet of residue here represents about 600 feet of dissolved salt. Overlying the dissolution residue a short distance from this location, are broken up terrigenous clastics of the Rustler Formation.

Stop 5: Rustler Formation (Culebra Dolomite) Outcrop

Excellent exposure of the lower Rustler Formation is present at this location, which is approximately 8 mi north of Malaga Bend, where it is thought that Culebra Dolomite-groundwater passing through the WIPP area discharges into the Pecos River (this is supported by potentiometric head data, but contradicted by water chemistry data-Neill, et al., 1983).

The outcrop we observed is composed (from bottom to top) of siltstone, brecciated dissolution residue, and the Culebra Dolomite. The Culebra Dolomite (fractured, fine crystalline dolomite; 25-30 ft thick) is the most hydrologically conductive unit in the Rustler; thus, the DOE assumes the Culebra is the bounding upper limit of subsurface radionuclide transport and will investigate it's hydrologic characteristics further (Neill et al., 1983).

The brecciated dissolution residue underlying the Culebra Dolomite at this location is a result of near-surface salt dissolution in the Rustler Formation. In fact, the Rustler salt thickens across the WIPP site from no salt present (completely dissolved) in the western portion, to a complete salt section in the eastern portion. As mentioned early, the EEG (Neill et al., 1983) has concluded that this near surface or "blanket" dissolution does not pose a threat to the WIPP repository, which is located 2160 ft below the surface.

Stop 6: Nash Draw

Nash Draw (fig. 4) is a northeast-trending depression (approximately 15 mi by 5 to 12 mi) that was formed by dissolution ("solution and fill" and "stratabound") of salt from the lower Salado and Rustler Formations (Bachman, 1981; Lambert, 1983). This process, which is responsible for the numerous caves and sinks in Nash Draw, has been active (and is presently active) since at least the beginning of the deposition of the Pleistocene Gatuna Formation (Bachman, 1981). We visited a small elongate depression (approximately 80 ft by 250 ft) with two dissolution caves that were large enough to crawl into and stand upright. Dr. Chaturvedi noted that large volumes of water disappear into these small caves during rainstorms, and that although an above average amount of rainfall occurred last year (25 in/yr), surface drainage in the area is poor (indicating recharge and facilitating more dissolution). After observing the sink, we drove eastward to see an outcrop of the uppermost Permian Dewey Lake redbeds on Livingston Ridge (fig. 4).

Stop 7: WIPP-12 Well

The WIPP-12 well (fig. 5) is located along the northern margin of WIPP Zone 2 (1 mile north of the surface facilities) and is one of three WIPP wells that was drilled as deep as the lower portion of the Castile Formation. During the drilling of this well in 1981, a pressurized brine reservoir (containing brine and gas) was encountered within vertically fractured anhydrite of the Castile Anhydrite Unit 3. In 1975, a similar occurrence was encountered in the Castile Anhydrite Unit 2 in the ERDA-6 well (Westinghouse, 1983; Neill et al., 1983). Hydraulic head values, pump test data, and chemical data suggest these brine reservoirs are not hydrologically connected with each other, or with underlying or overlying strata (Borns et al., 1983; Westinghouse, 1983). Instead, the brine pockets discovered to date are isolated reservoirs associated with salt flow anticlines of the Castile "deformed zone", which is thought to be an area where differential stresses led to salt flow, fracturing in overlying anhydrite, and subsequent concentration of formation fluid and gas in the fractured horizons (Westinghouse, 1983).

Although pressurized brine has not affected excavations at the present-day WIPP facility, the discovery of the brine reservoirs in ERDA-6 and WIPP-12 led to the relocation of the WIPP site (to the south of the original pre-ERDA-6 location) and the southward reorientation of the long axis of the underground facility (away from WIPP-12). The EEG has recommended that the DOE utilize geophysical techniques such as Controlled Source Audio Magneto-Telluric (CSAMT) to attempt to identify brine reservoirs beneath the site (WIPP-Zone 2) (Neill et al., 1983).

Stop 8: WIPP-33 Well

The WIPP-33 well (fig. 5) was drilled into a bowl-shaped surface depression (approximately 2.75 miles from the WIPP) that is suspected to be the eastern-most geomorphological expression of Nash Draw-type salt dissolution in the vicinity of the WIPP. I estimate this sink is 250-350 ft in diameter, and outcrops of Dewey Lake Redbeds that are overlain by Mescalero Caliche form the high-standing, outer rim. Drilling fluid loss and drill bit slippage (indicating highly porous rock) during WIPP-33 operations suggest this surface depression is a result of dissolution. In addition, rainfall in the vicinity of the WIPP-33 depression seems to drain into this feature.

Stop 9: Hill A Breccia Pipe (Breccia Chimney)

Due to time limitations, the group was not able to visit Hill A Breccia Pipe on 2/27 as planned; however, Jim Warner went to this deep-seated dissolution feature the following day. On the surface, Hill A Breccia Pipe is a small dome (approximate diameter - 1000 ft) with a bowl-shaped central depression (approximate relief - 50 ft) that is enclosed by a circular ring fault (Bachman, 1980). The outer slope of the dome is composed of normally-stratified Dewey Lake Redbeds, Triassic sandstone, and Pleistocene Mescalero Caliche that dip 15°-20° away from the center. The drilling of the WIPP-31 well (located in the center of the breccia pipe) showed that dissolution/collaspe breccia of Salado and younger strata make up the core of this breccia pipe, and that most of the Salado and Rustler salt have been removed by dissolution (Synder and Gard, 1982). Synder and Gard (1982) attributed this and other similar features (Hill C Breccia Pipe) to cavernous collapse within the underlying Capitan Reef, followed by salt dissolution and subsidence (prior to, during, and after the deposition of the Mescalero Caliche 500,000 years ago). However, borehole WIPP-31 did not penetrate beneath brecciated rock into the Capitan Reef (Snyder and Gard, 1982).

Conclusions

This trip was extremely informative from both a technical and a regulatory point of view. Exposure to the evidence for the geologic and hydrologic processes that are relevant to the performance of the WIPP, and the techniques used to assess their importance, was a valuable experience. In addition, discussions with Dr. Chaturvedi concerning the EEG's contributions to issue resolution were interesting. Thus, it is recommended that NRC staff monitor progress at the WIPP and request a visit to the subsurface facilities at some future date.

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